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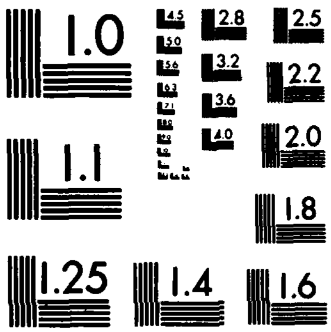

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Long-Term Load Performance of Hardboard I-Beams

J. Dobbin McNatt
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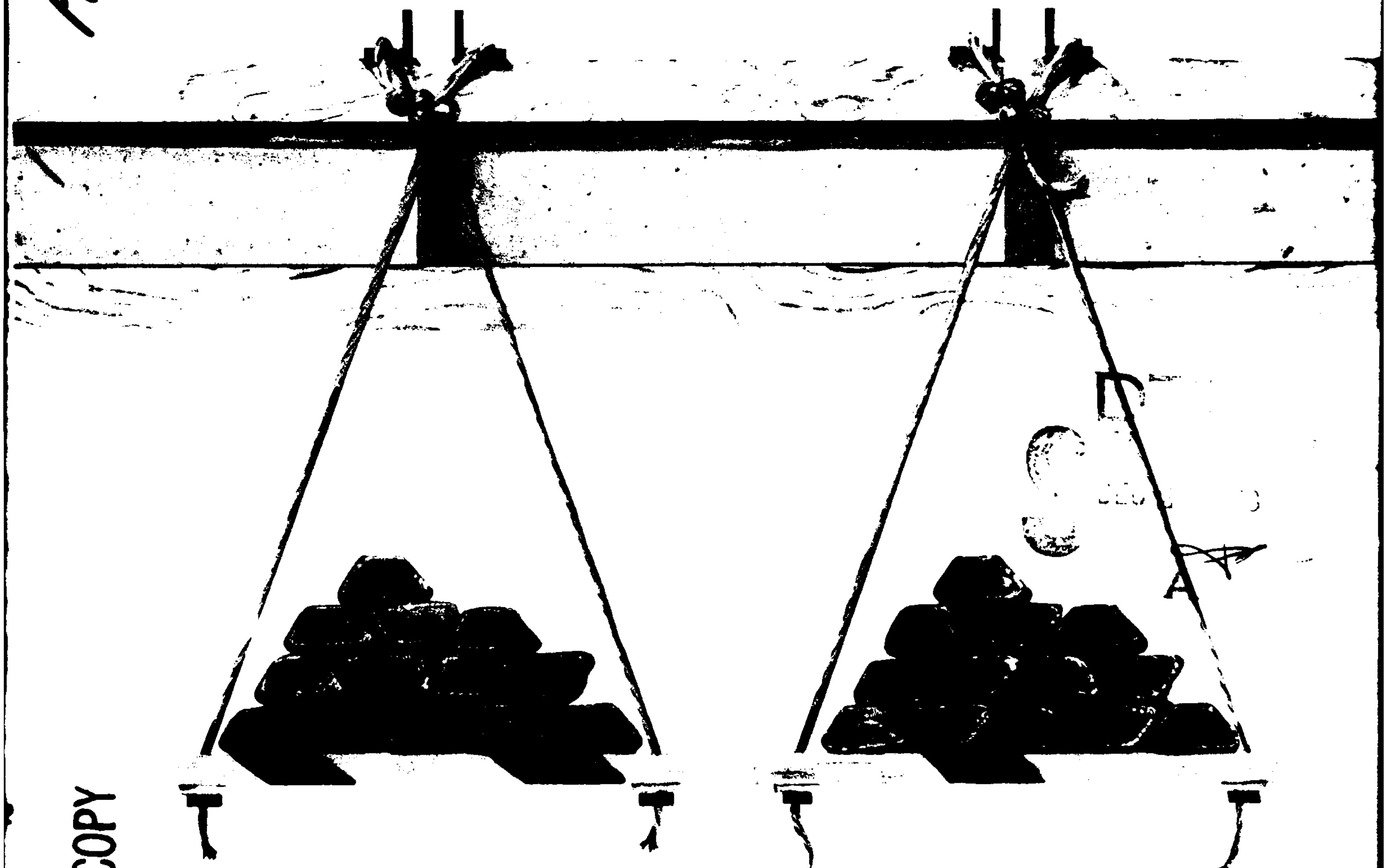

Abstract

Built-up I-beams with hardboard shear webs and laminated-veneer lumber flanges exhibited satisfactory performance when subjected to constant loads for up to 5 years in interior, protected exterior, and controlled cyclic humidity environments. Creep deflection was greatest for beams in the cyclic humidity environment and least for those in the interior environment. For beams loaded at the same stress level in a given environment, deflection was greater for beams made with web material having the lower shear stiffness. Except for 6-foot beams in the cyclic humidity environment, static tests on beams after long-term loading did not reveal any loss in strength or stiffness.

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November 1983

Long-Term Load Performance of Hardboard I-Beams

J. Dobbin McNatt, Technologist
and
Michael J. Superfesky, Engineer

Introduction

Increasing costs and decreasing availability of larger, solid-sawn wood joists for roof and floor systems have encouraged the development of prefabricated beams of various types. Nelson *(15)*[2] has stated that it is possible to save up to 50 percent of the wood fiber by forming the wood material from the log into more efficient, lighter weight structural shapes such as I-beams and box beams. Furthermore, these structural components save considerable time and labor because they are premanufactured to the desired length and are capable of multiple spans without splicing.

The performance of structural I-beams and box beams is highly dependent on the shear properties of the web materials. Some wood-base panel materials, such as hardboard, possess shear properties that indicate a good potential for web materials in built-up beams. These and other products are being investigated for use in composite structural members.

Although encouraging reports have described use of hardboard-webbed I-beams in Europe and elsewhere *(4,5,8-10,12)*, such uses of hardboard in the United States have so far been restricted to research projects. Figure 1 shows hardboard-webbed I-beams being used in London, England. The beams are 39 feet long, 24 inches deep, and the hardboard web material is 5/16 inch thick.

Studies at the Forest Products Laboratory (FPL) demonstrated that short-term strength and stiffness of hardboard I-beams could be predicted using fundamental engineering theory and basic material properties *(16,21)*. A later study demonstrated that 12- foot-long beams with hardboard shear webs did not fail when loaded for 2 years in uncontrolled interior or protected exterior environments. However, 6-foot-long hardboard I-beams loaded at higher stress levels in a cyclic humidity environment deflected considerably, and two beams actually failed *(20)*. A summary of research on, and use of, hardboard beams is presented in a Forest Products Journal article *(11)*.

This paper covers the following performances: Eight 12-foot beams, each loaded for 5 years in the interior or exterior exposure; eight 12-foot beams, each loaded for 2 years in the cyclic humidity environment; and eight 6-foot beams, each loaded for 4 years in the exterior exposure. Some results are compared with results previously reported *(20)*.

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[1] The Laboratory is maintained in cooperation with the University of Wisconsin.

[2] Italicized numbers in parentheses refer to literature cited at end of report.

Description of Materials

Web Materials

Three different web materials were used in construction of the I-beams. Two were commercial 1/4- inch-thick, high-density, tempered hardboards: Hardboard A, dry-formed and dry-pressed; hardboard B, wet-formed and wet-pressed. The third material was 1/4- inch-thick, Exterior, Group I, Douglas-fir plywood. The plywood was included to provide a basis for judging the performance of the hardboard-webbed I-beams. This particular plywood was chosen so that comparisons could be made on a thickness-for-thickness basis. However, it should be pointed out that fabricators of plywood I-beams commonly use 3/8- and 5/8-inch Structural I or C-D Exterior panels, not 1/4- inch plywood. The thicker material reduces buckling tendencies, and intermediate stiffeners are not used.

Some basic strength and elastic properties of the web materials are given in table 1. Of particular importance to this study are the shear properties of the web materials. Average shear strength through the thickness as determined by the rail shear test method *(3)* for hardboard B (4,200 lb/in.^{2}) was 38 percent greater than the shear strength of hardboard A (3,040 lb/in.^{2}). Hardboards A and B, respectively, were about three and four times stronger in shear through the thickness than the plywood (960 lb/in.^{2}). Shear strength through the thickness for plywood was measured parallel to the grain of the face plies. A few exploratory tests indicated that shear strength at a 45° angle to the grain for this plywood was two to three times greater than strength parallel to the face grain. This difference is recognized in published allowable stresses for plywood (*1*, table 3, page 17). Shear modulus values of hardboards A (321,000 lb/in.^{2}) and B (334,000 lb/in.^{2}) differed by only a few percent, but averaged about four times the plywood shear modulus (83,000 lb/in.^{2}) as measured by the plate shear test method *(2)*.

Flange Material and Web Stiffeners

The I-beam flanges were cut from parallel-laminated wood veneer panels 15 feet long, 25 inches wide, and 1-1/2 inches thick. A nondestructive test method was used to determine bending stiffness of each piece of flange material. Each 1-1/2- by 2-1/8-inch by 12-foot piece was simply supported at the ends with vertically oriented laminations (2-1/8-in. dimension) and vibrated transversely at its natural frequency. The elastic modulus was calculated using vibration frequency and specimen weight and dimensions. To minimize variation in beam stiffness, pieces of flange material with the closest values of elastic moduli were then matched in groups of four for use in the same beam.

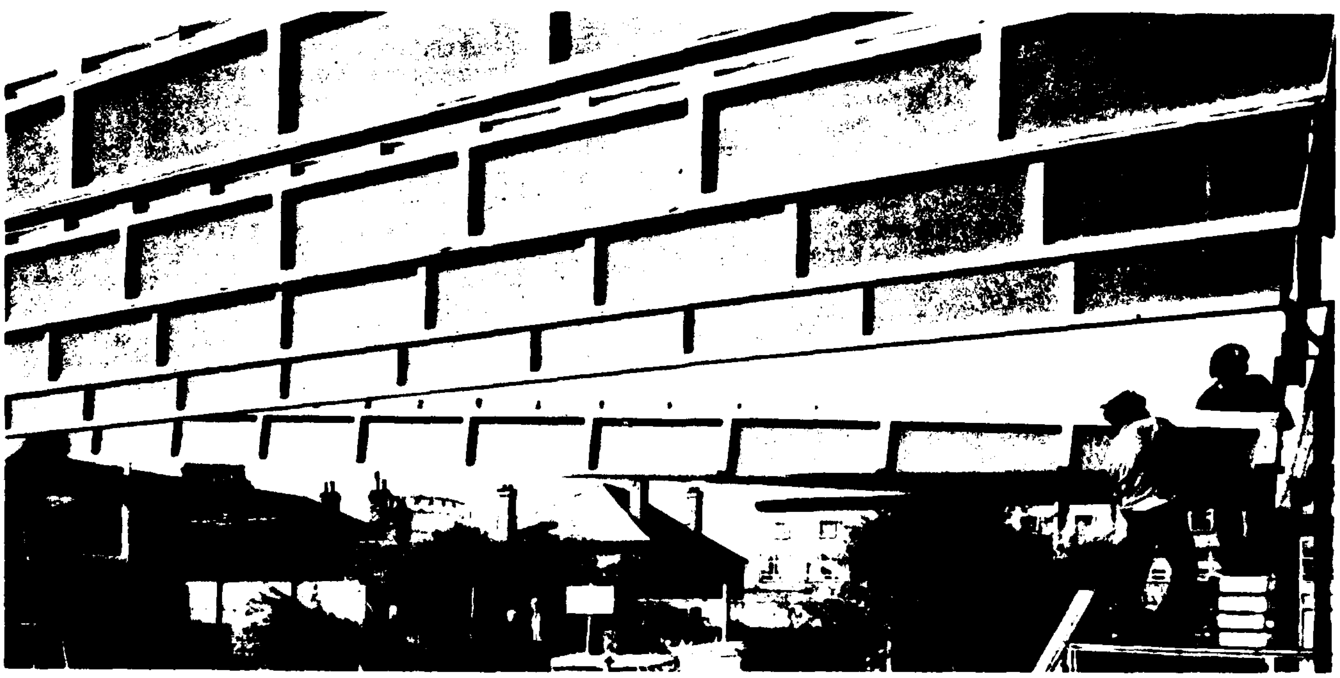

Figure 1.—Twelve-meter-long hardboard-webbed I-beams for roof of Post Office sorting building at Southhall, London, England, 1975 (courtesy of Fiber Building Board Development Organization, Ltd., London). (M151694-17)

Table 1.—Some basic strength and elastic properties of web material used in this study

Type of test[1]	Number of speci-mens	Strength[2]		Elastic modulus[2]	
		Average	Standard devia-tion	Average	Standard devia-tion
		Lb/in.2			
HARDBOARD A[3]					
Compression parallel	10	4,640	600	762,000	54,000
Tension parallel	24	4,740	380	764,000	40,500
Rail shear	24	3,040	240	—	—
Plate shear	24	—	—	321,000	19,200
HARDBOARD B[3]					
Compression parallel	10	5,700	540	864,000	59,000
Tension parallel	24	6,050	540	850,000	72,500
Rail shear	24	4,200	400	—	—
Plate sheer	24	—	—	334,000	18,300
PLYWOOD[3]					
Compression parallel[4]	9	4,800	920	1,441,000	433,000
Tension parallel[4]	20	5,800	1,100	1,386,000	221,700
Rail shear[4]	20	960	70	—	—
Plate shear	20	—	—	83,000	11,500

[1] Tests made in accordance with ASTM D 1037-72 *(3)* except plate shear modulus (modulus of rigidity) was determined by the procedure used for plywood, ASTM D 3044-72 *(2)*.

[2] Values calculated as if materials were homogeneous.

[3] Hardboard A—a 1/4-inch-thick, dry-felted, dry-pressed, high-density, tempered hardboard. Hardboard B—a 1/4-inch-thick, wet-felted, wet-pressed, tempered hardboard. Plywood—a 1/4-inch-thick, exterior Group 1, Douglas-fir plywood.

[4] Load applied parallel to grain of face ply.

To check the reliability of the data from the vibration tests, stiffness of 11 pieces of flange material was determined using the nondestructive transverse vibration method, and then each piece was loaded statically in bending using quarter-point loading on an 11-foot span. The average modulus of elasticity determined by the vibration procedure (2.13×10^6 lb/in.^{2}) was only 3 percent greater than that determined by the static bending test (2.07×10^6 lb/in.^{2}). Web stiffeners were cut from nominal 2-inch-dimension Construction lumber.

Construction of I-Beams

Figure 2 shows dimensions and cross sections of the 6- and 12-foot-span I-beams used in this study. Beams for a 12-foot span were designed to carry 100 pounds per lineal foot (lb/lin ft) without exceeding a web shear stress of 250 lb/in.^{2}. This 100-lb/lin-ft load is based on a 50 lb/ft^2 floor load and a 24-inch joist spacing. The 6-foot beams were fabricated in order to include I-beams with a high probability of web shear failure. A phenol-resorcinol adhesive was used to bond the materials. A total of thirty-eight 6-foot-span beams (32 hardboard and 6 plywood) and thirty-six 12-foot-span beams (24 hardboard and 12 plywood) were fabricated and evaluated.

Experimental Procedure

Control Beams

Twelve each of the 12- and 6-foot-span I-beams (eight hardboard and four plywood) were tested statically to compare actual and theoretical load-deformation performance under short-term loading. Six-foot beams were loaded at midspan. Twelve-foot beams were loaded at 2-foot intervals using the cable/pulley arrangement shown in figure 3. These tests were discussed in detail in an earlier report *(21)* and results are summarized in table 2. Final failure of all the 12-foot hardboard control beams occurred in the tension flange. Final failure of the 12- and 6-foot plywood beams occurred in shear in the web, parallel to the grain of the face plies.

All the 6- foot hardboard control beams failed in diagonal tension-compression in the web (see fig. 4). This type of failure is typical for hardboard beams designed to fail in the web *(6)*. Relative strengths and stiffnesses of beams made with hardboards A and B reflect the relative shear strengths and stiffnesses of hardboards A and B (table 1). The "B" beams were 31 percent stronger than the "A" beams, but stiffnesses of "A" and "B" beams were nearly equal.

Long-Term Loading

Groups of beams were loaded in each of three different environments—controlled cyclic, uncontrolled interior, or protected exterior—described in table 3. Eight of the 6-foot hardboard beams were stored, unloaded, in the protected exterior environment.

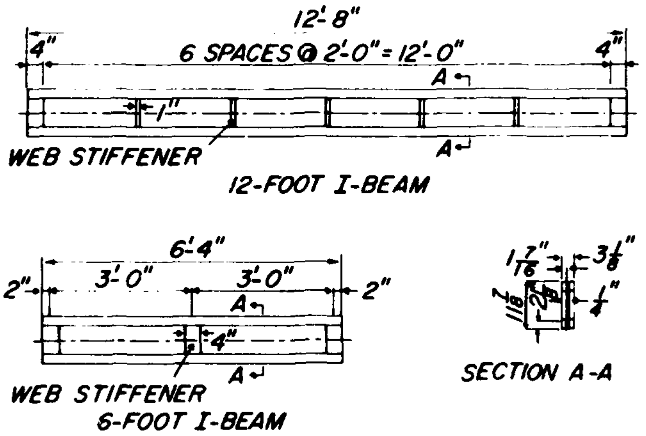

Figure 2.—Details of the 6-foot and 12-foot I-beams used in this study. (M143780)

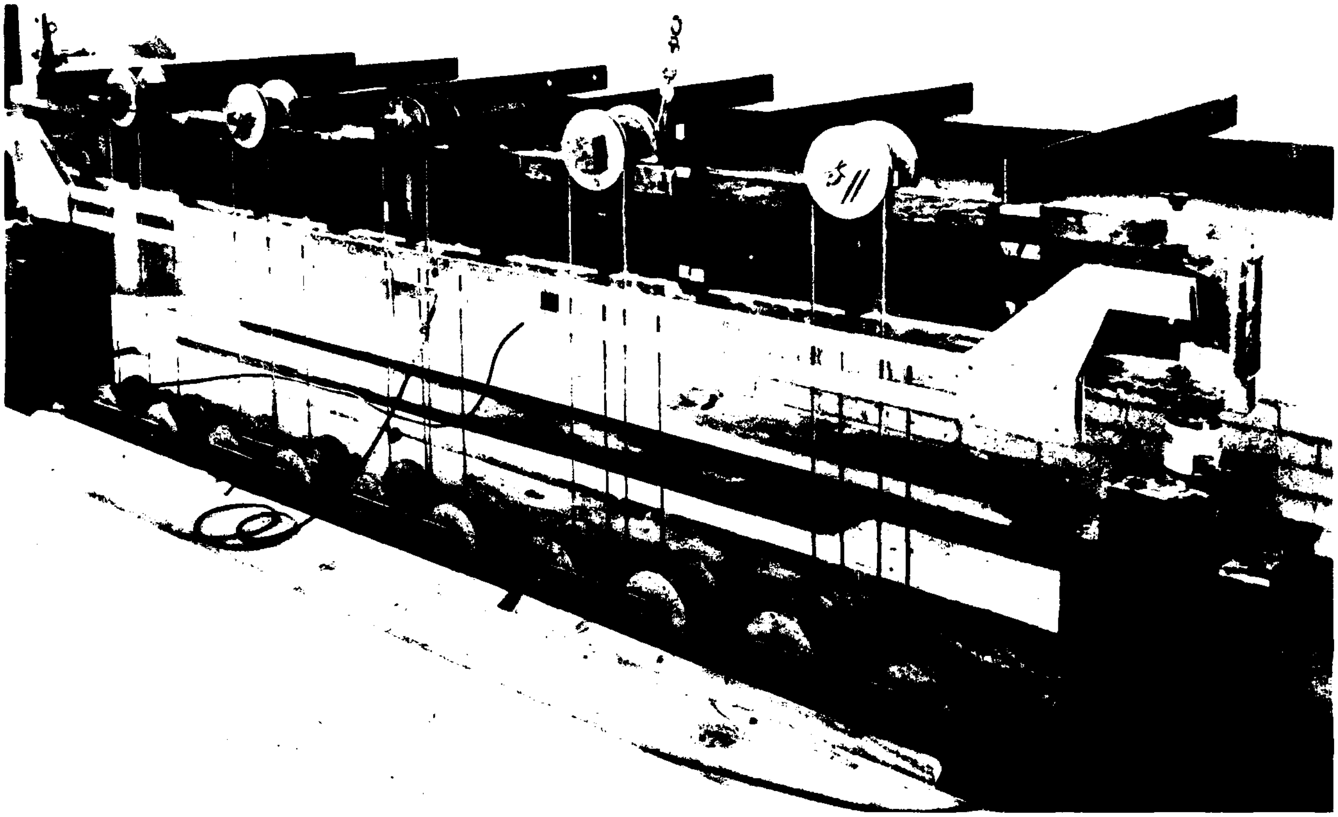

Figure 3.—Method of statically testing 12-foot-long I-beams after long-term loading. (M147566)

Figure 4.—Diagonal tension-compression failure in 6-foot hardboard-webbed I-beam controls. (M141032)

Environment 1 (controlled cycle) was selected because of reports in references 13 and 17 that cyclic moisture conditions and increased moisture content accelerated the creep rate of small, hardboard bending specimens. Environments 2 (uncontrolled interior) and 3 (protected exterior) were selected to simulate the type of exposure that the I-beams might encounter in actual use.

All 12-foot I-beams were loaded at five equally spaced points (fig. 5) to produce a web shear stress of 250 lb/in.^{2}. This is 8 percent, or less, of hardboard shear strength, and is 26 percent of plywood shear strength.

Analysis of Results

Table 2.—Summary of I-beam short-term tests: From *(21)*

6-foot beams		12-foot beams	
Maximum load	Load-deflection ratio[1]	Maximum load	Load-deflection ratio[1]
Lb	Lb/in.	Lb	Lb/in.
HARDBOARD A			
11,800	37,900	12,100	10,700
HARDBOARD B			
15,400	36,900	15,800	11,300
PLYWOOD			
6,400	19,800	6,000	7,700

[1] Slope of the initial linear portion of the load-deflection curve.

Table 3.—Number of beams receiving each treatment

Environment	Conditions	6-foot Hardboard A	6-foot Hardboard B	6-foot Plywood	12-foot Hardboard A	12-foot Hardboard B	12-foot Plywood
Controlled cyclic	80° F and cyclic RH (one complete RH cycle = 20 pct RH for 48 h, 80 pct RH for 48 h)				2	2	4
Uncontrolled interior	Single-story timber arch mill building heated during winter months				3	3	2
Protected exterior	Roofed pole building with all sides open to the weather	4	4		3	3	2

The 6-foot I-beams were loaded at midspan using a lever system that provided a 4 to 1 mechanical advantage and could apply the same load to two beams at the same time. End reactions of each beam were initially measured using electrical load cells to ensure that the total applied load was properly transmitted to each beam. Loads applied to the 6-foot I-beams induced web shear stresses of either 15 percent or 25 percent of the rail shear strength of the web material (table 1). The 15 percent stress level was selected based on a publication by Lundgren *(9)* in which he suggested 15 percent of ultimate as a maximum shear stress for beams exposed to the elements for extended periods. A stress level of 25 percent of ultimate was assumed to be an upper limit for design.

Results of 2 years' loading of the 6-foot-span beams in the cyclic humidity condition and the 12-foot beams in the interior and exterior environments have been reported earlier *(20)*.

Six-Foot Beams in Protected Exterior Environment

After 4 years under load, 6-foot hardboard-webbed I-beams loaded to 15 percent of the maximum shear strength of the hardboard had deflected approximately 0.25 inch; beams loaded to 25 percent of the hardboard shear strength had deflected approximately 0.40 to 0.50 inch (fig. 6).

At both stress levels, the 6-foot beams made with hardboard B deflected more than those made with hardboard A, even though they were both stressed at the same percent of maximum shear strength. (Hardboard "B" was 38 pct stronger in shear than "A;" therefore, "B" beams carried 38 percent more load than "A" beams.) Because shear stiffness of the two hardboards and that of beams made from them were nearly the same, beams carrying the greater load would be expected to deflect more.

Controlled Cyclic Versus Protected Exterior Environment

In the controlled cyclic exposure, temperature was kept essentially constant at 80° F, and humidity changed every 48 hours between 20 percent and 80 percent. Transition of the room from 20 percent to 80 percent or from 80 percent to 20 percent relative humidity (RH) took a total of about 5 or 6 hours, although most all the change took place in the first hour or two.

For the exterior exposure, outdoor temperature varied over the year from well below 0° to above 90° F while RH generally ranged between 30 percent and 90 percent. Outdoor temperatures and humidity were also inversely related. That is, a check of local climate data for Madison, Wis., *(14)* showed that for daily temperature/humidity fluxuations, RH increased as temperature decreased (fig. 7).

The same outdoor temperature/humidity relationship was reported by Tyne *(22)* for London, England. Schniewind and Lyon *(18,19)* approximated this situation when they loaded small Douglas-fir beams in a cyclic temperature/humidity environment. The temperature cycle was sinusoidal between 60° and 90° F over a 24-hour period; the RH cycle was between 35 percent and 87 percent over a 24-hour period, but 180° out of phase with temperature change (called Condition *D*). Matched beams were loaded in an environment with the same humidity cycling (35 pct to 87 pct RH), but at a constant temperature of 75° F (24° C) (called Condition *A*). For beams loaded at 70 percent of their estimated bending strength, average time to failure was about 5-1/2 days (7,950 min) in Condition D— and only about 1 day (1,445 min) in Condition *A*.

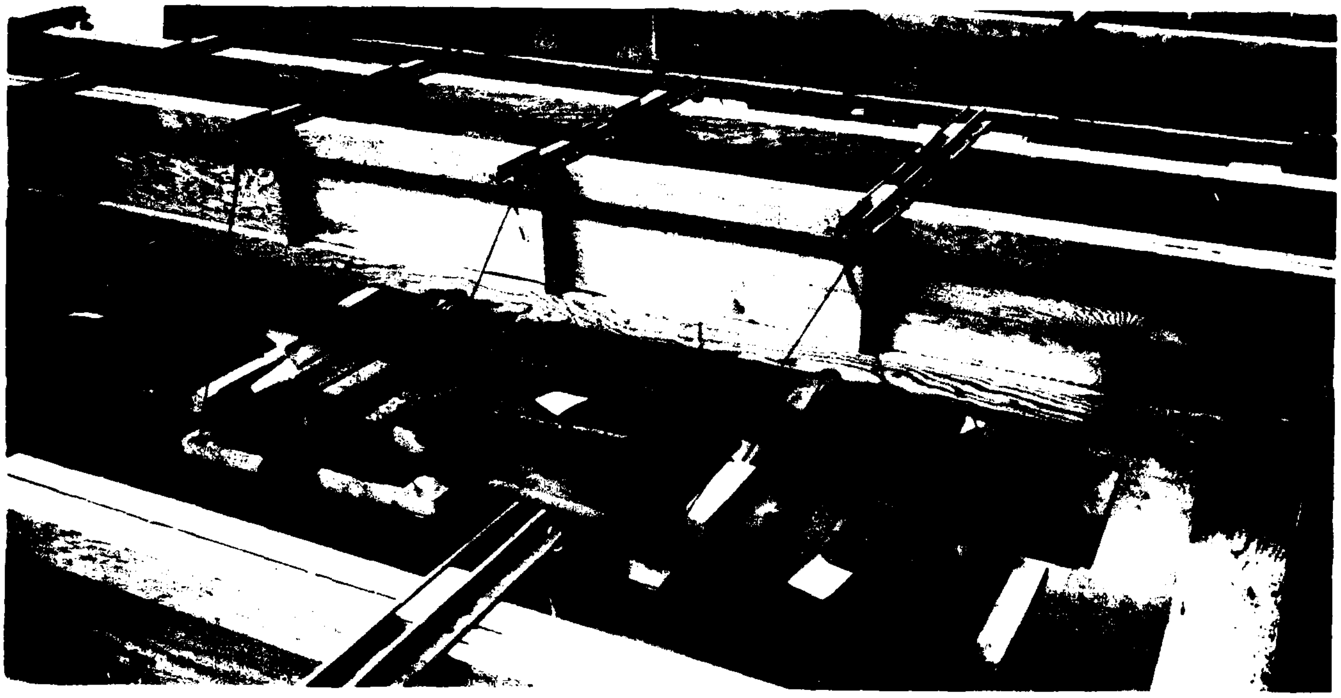

Figure 5.—Method of applying constant load to 12-foot-long I-beams. (M142281)

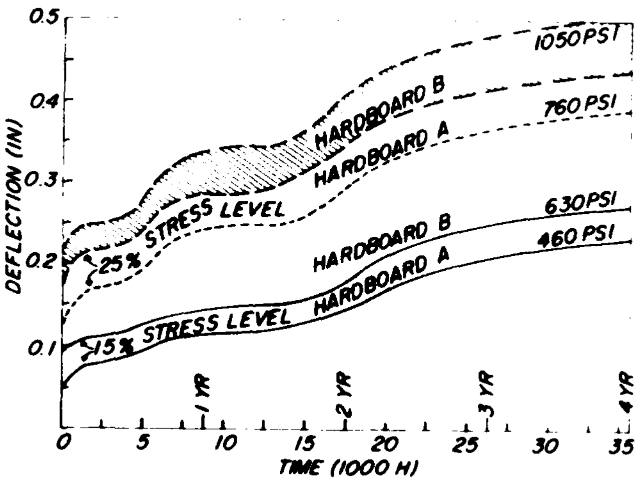

Figure 6.—Deflection versus time for 8-foot-long hardboard-webbed I-beams at different levels of web shear stress in a protected exterior environment. (M151786)

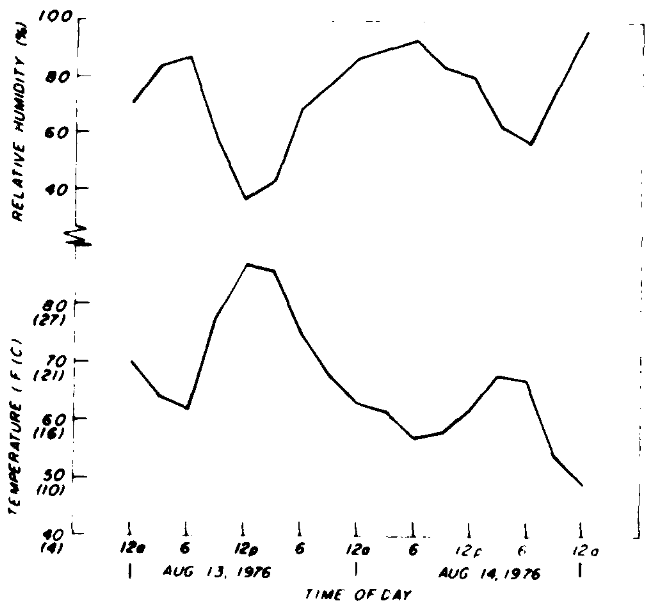

Figure 7.—Outdoor temperature/RH relationship in exterior environment over a specific 2-day period in Madison, Wis (14). (M151788)

Figure 8 shows that the controlled cyclic humidity exposure caused much greater deflection of the 6-foot beams loaded at the 15 percent stress level than did the actual exterior exposure. This result agrees, in principle, with work done by Schniewind and Lyon *(18,19)*.

Residual strength of the 6-foot beams after 4 years under load in the exterior environment is discussed in a later section.

Twelve-Foot Beams in Uncontrolled Interior Environment

Figure 9(a) shows deflections of the 12-foot I-beams in the uncontrolled interior environment. All beams were loaded to a web shear stress of 250 lb/in.². As this load is 26 percent of the plywood shear strength but only about 8 percent or less of the hardboard shear strength (table I), it is to be expected that total midspan deflection after 5 years under load was more for the plywood-webbed beams (0.285 and 0.325 in.) than for the hardboard-webbed I-beams (0.170 to 0.195 in.). Apparent dramatic deflection increases occurred between 12,500 and 15,000 hours and between 30,000 and 35,000 hours because of humidity changes in the uncontrolled environment. In fact, the total increase in deflection was only 0.02 inch between points *1* and *2* and less than 0.04 inch between *3* and *4*. Results of earlier tests on 6-foot beams in the cyclic humidity condition *(20)* indicated that performance of plywood beams at a 26 percent stress level (250 lb/in.²) was similar to that of hardboard beams at a 15 percent stress level (hardboard A beams 460 lb/in.² and hardboard B beams 630 lb/in.²).

Creep deflection after 5 years in the interior environment (total minus initial) was about 78 percent of the initial deflection for the hardboard beams and about 100 percent for the plywood beams.

Twelve-Foot Beams in Protected Exterior Environment

Deflections of the hardboard and plywood beams (12-ft span) in the exterior environment are shown in figure 9(b). As in the interior environment, web shear stress was 250 lb/in.², and the beams were loaded for 5 years. As expected, total deflection after 5 years was less for the hardboard beams (0.250 to 0.320 in.) than for the plywood beams (0.465 and 0.595 in.).

Total deflection of the hardboard beams after 5 years under load in the exterior environment averaged 60 percent greater than deflection in the interior environment. Plywood beam deflection averaged 70 percent greater. In the exterior environment, creep deflection was about 120 percent of the initial deflection for the hardboard beams and 140 percent for the plywood beams. For both the hardboard and plywood beams, creep deflection after 5 years under load in the exterior environment averaged twice the deflection in the interior environment.

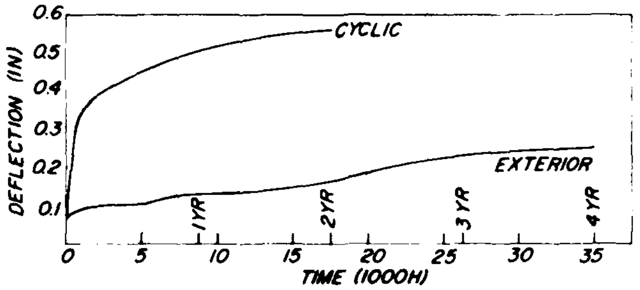

Figure 8.—Deflection versus time for 6-foot-long hardboard-webbed I-beams at 15 percent stress level in controlled cyclic and protected exterior environments. (M151787)

Twelve-Foot Beams in Cyclic Humidity Condition

Figure 9(c) shows the deflection of the 12-foot hardboard and plywood I-beams loaded for 2 years in the controlled cyclic humidity condition. All the beams were loaded to produce a web shear stress of 250 lb/in.².

In this more severe condition, beams made with hardboard B, the stronger of the two products, deflected somewhat less than beams made with hardboard A. After 2 years under load, total deflection averaged 0.245 inch for the two hardboard B beams and 0.375 inch for the two hardboard A beams. Total deflection of the four plywood beams averaged 0.820 inch. Creep deflection was almost 3-1/2 times initial deflection for the hardboard A beams, almost two times initial deflection for the hardboard B beams, and four times initial deflection for the plywood beams.

Compared with the 2-year deflections of the 12-foot beams loaded at the same stress level, creep deflection in the cyclic exposure averaged almost four times that in the interior exposure for the hardboard beams and more than 5-1/2 times for the plywood beams.

Bending Strength and Stiffness After Long-Term Loading

Six-foot beams.—After 4 years under load in the protected exterior environment at a shear stress level of 15 percent or 25 percent of the shear strength of the hardboard, the eight 6-foot beams were unloaded, reconditioned at 50 percent RH for 5 weeks, and tested statically (midspan loading). At the same time eight similar beams, which had been stored in the same area but not loaded, were tested. Results of these tests are given in table 4. One of three types of failure occurred: (1) Glueline shear failure between the hardboard web and the laminated veneer flange (failure was in the surface of the hardboard); (2) failure of the tension flange; (3) Diagonal tension-compression failure in the hardboard web (fig. 4).

As shown in table 4, all five of the beams that failed in glueline shear were made with hardboard A, and all six of the beams that failed in tension in the lower flange were made with hardboard B. In addition, three of the hardboard A beams and two of the hardboard B beams failed in diagonal tension-compression in the web. Values in table 4 indicate that the mode of failure did not affect beam strength. The values also suggest that strength and stiffness were not affected by long-term loading at either the 15 percent or 25 percent stress level.

Twelve-foot beams.—The twenty-four 12-foot I-beams (figs. 9(a)(b)(c)) loaded either for 2 years in the cyclic humidity condition or for 5 years in the interior or exterior environment were unloaded, reconditioned for 5 weeks, and tested statically. The test procedure used is shown in figure 3 and discussed in detail in *(21)*. Results of the tests are given in table 5.

Six of the hardboard A beams failed in diagonal tension-compression in the hardboard web, one in tension in the lower flange, one in glueline shear between the web and flanges. Four of the hardboard B beams failed in diagonal tension-compression in the web, and four in tension in the lower flange. As with the 6-foot beams, there does not appear to be a relationship between maximum load and mode of failure.

All eight plywood beams failed in shear through the thickness of the plywood web, parallel to the grain of the face plies that ran parallel to the length of the beam. It is possible that the failure mode and maximum loads for these beams would be different for a different face-grain orientation. The usual practice in fabricating plywood I-beams is to orient the face grain vertically. Fawcett and Sack *(7)* reported that strength of plywood I-beams increased as the number of plies with grain at 90° to the beam length was increased.

Strength and stiffness of the 12-foot hardboard beams averaged slightly higher for the beams tested after long-term loading than for similar beams tested earlier *(21)* without being subjected to dead load or exposure other than normal interior conditions (table 2). Strength and stiffness of the 12-foot plywood beams after long-term loading averaged about 5 percent less than similar beams not dead loaded.

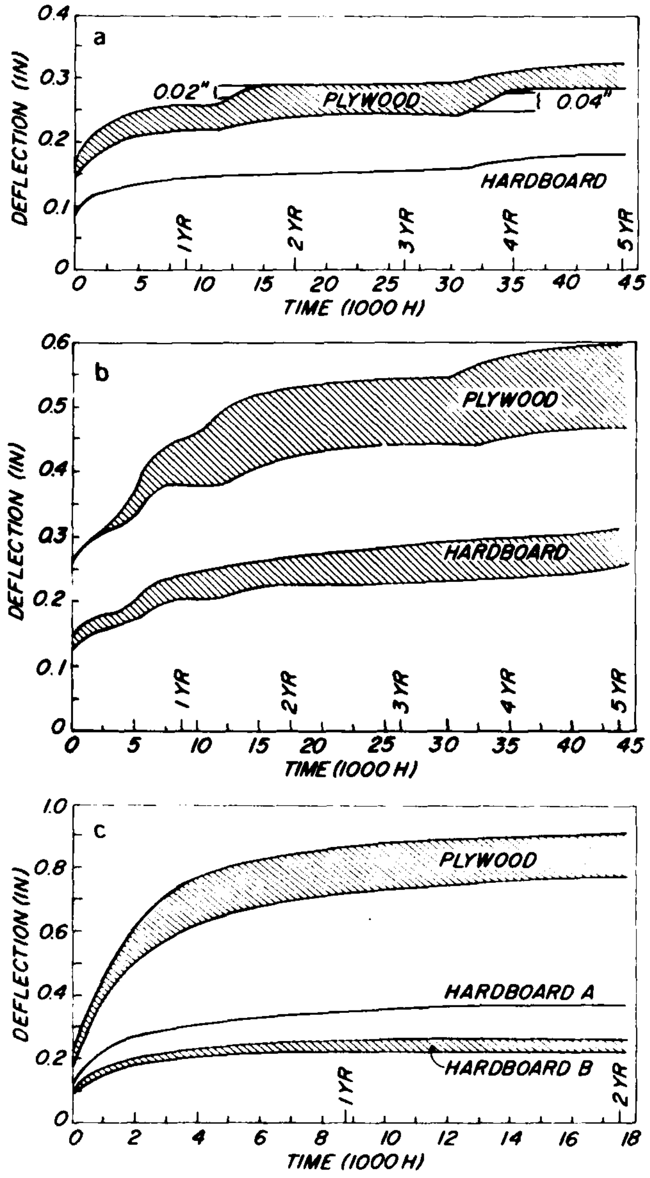

Figure 9.—Deflection versus time for 12-foot-long I-beams under a constant web shear stress of 250 lb/in.²: a. In an uncontrolled interior environment; b. in a protected exterior environment; c. in a cyclic humidity environment. (M151789, M151790, M151791)

Table 4.—Strength and stiffness of 6-foot hardboard-webbed I-beams after 4 years in protected exterior environment

Hardboard	Number of beams	Maximum load: Average	Maximum load: Range	Load-deflection ratio[1]: Average	Load-deflection ratio[1]: Range	Failure types[2]
		------Lb------		-----Lb/in.-----		
LOADED AT 15 PERCENT STRESS LEVEL						
A	2	12,300	11,600 & 13,000	35,300	32,800 & 37,800	1,1
B	2	18,000	16,500 & 19,500	46,200	44,900 & 47,600	2,2
LOADED AT 25 PERCENT STRESS LEVEL						
A	2	12,400	11,400 & 13,400	34,800	33,200 - 36,400	1,3
B	2	18,000	17,500 & 18,400	37,100	32,600 & 41,700	2,3
STORED BUT NOT LOADED						
A	4	12,700	11,400 - 14,600	33,600	31,200 - 35,200	1,1,3,3
B	4	16,300	15,500 - 17,800	36,200	31,700 - 42,600	2,2,2,3

[1] Slope of the initial straight-line portion of the load-deflection curve.

[2] 1 = Glueline shear between web and flanges; 2 = tension in the lower flange; 3 = diagonal tension-compression in the web.

Table 5.—Strength and stiffness of 12-foot hardboards and plywood-webbed I-beams after being loaded at 250 pounds per square inch in interior, exterior, and cyclic humidity environments

Web material	Number of beams	Maximum load: Average	Maximum load: Range	Load-deflection ratio[1]: Average	Load-deflection ratio[1]: Range	Failure types[2]
		------Lb------		-----Lb/in.-----		
UNCONTROLLED INTERIOR ENVIRONMENT (5 YR)						
Hardboard A	3	13,300	12,800 - 13,600	11,700	11,200 - 12,500	3,3,3
Hardboard B	3	18,000	15,800 - 19,800	12,200	11,400 - 13,000	2,2,2
Plywood	2	6,400	6,400 & 6,400	6,700	6,700 & 6,800	4,4
PROTECTED EXTERIOR ENVIRONMENT (5 YR)						
Hardboard A	3	13,500	12,900 - 13,900	10,600	10,000 - 11,100	2,3,3
Hardboard B	3	15,500	13,700 - 18,600	11,300	11,100 - 11,600	2,3,3
Plywood	2	5,800	5,600 & 6,000	7,000	6,900 & 7,000	4,4
CYCLIC HUMIDITY ENVIRONMENT (2 YR)						
Hardboard A	2	13,700	13,500 - 13,800	11,400	11,400 & 11,400	1,3
Hardboard B	2	18,400	17,800 & 19,100	11,300	10,800 & 11,700	3,3
Plywood	4	5,300	5,100 - 5,400	5,900	5,600 - 6,100	4,4,4,4

[1] Slope of initial straight-line portion of load-deflection curve.

[2] 1 = Glueline shear between web and flanges; 2 = tension in the lower flange; 3 = diagonal tension-compression in the web; 4 = shear through the thickness, parallel to grain of face plies.

Conclusions

The conclusions below are based on long-term (up to 5 yr) loading of 32 hardboard-webbed and 8 plywood-webbed I-beams, either 6 or 12 foot long. Loading took place in one of three environments: uncontrolled interior, protected exterior, and controlled cyclic humidity.

1. For beams loaded to the same web shear stress, those with hardboard webs deflected less than those with plywood webs of equal thickness since the hardboard was three to four times stiffer in shear through the thickness than the plywood for the plywood grain orientation used.

2. Creep deflection was greatest for beams loaded in the controlled cyclic humidity environment, intermediate for those in the protected exterior environment, and least for those loaded in the uncontrolled interior environment. This means that cycling between high and low humidity at a constant temperature produces more creep deflection than would be likely in actual use.

3. Results of load-to-failure tests on beams in this study after long-term loading did not indicate any loss in strength or stiffness except for 6-foot beams loaded in the cyclic humidity environment. Previous work *(20)*, however, indicated that the 6-foot beams loaded for 2 years in the cyclic-humidity environment had decreased in strength and stiffness.

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McNatt, J. Dobbin: Superfesky, Michael J. Long-term load performance of hardboard I-beams. USDA Forest Serv. Res. Pap. FPL 441. Madison, WI: Forest Products Laboratory; 1983. 10 pp.

Built-up I-beams with hardboard shear webs and laminated veneer lumber flanges exhibited satisfactory performance when subjected to constant loads for up to 5 yr in interior, exterior, and controlled cyclic humidity environments. Beams loaded to failure after these exposures showed little, if any, loss in strength and stiffness.

KEY WORDS: Beams; Deformation; Hardboard; Long-term load; Plywood; Wood construction

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